NOVA/BEAMLET/NIF UPDATES OCTOBER–DECEMBER 1997

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Nova Operations

Nova Operations performed 180 full system shots resulting in 197 experiments during this quarter. These experiments supported efforts in ICF, Defense Sciences, university collaborations, Laser Science, and Nova facility maintenance. At the beginning of the quarter the operation of Nova was reduced to 1.5 shifts. Toward the end of the quarter, Bechtel Nevada agreed to provide support for the operation of the target bay. This increase in staffing will allow Nova to again operate for two shifts per day later in the year, increasing the original goal of 700 experiments in FY98 to 900 experiments.

The final shots were fired into the two-beam target chamber this quarter. The two-beam facility was turned over to the NIF project as scheduled. (This process began in mid-November and was completed by the middle of January.)

The Petawatt system underwent a major reconfiguration to add a deformable mirror to the front end of the beamline. In preparation for focal-spot control test shots early in the next quarter, the deformable mirror was installed in conjunction with Hartmann sensors in the Petawatt master oscillator room (MOR), the beamline 6 output sensor, and the compressed beam diagnostic station. Many new diagnostics were installed on the Petawatt target chamber in preparation for the fast ignitor and radiography experiments that will be performed with focal-spot control.

Beamlet Operations

Beamlet completed a total of 40 shots in 16 shot days this quarter. Pinhole closure experiments were performed in October to evaluate the performance of a conical and pyramidal pinhole design of several sizes. Later in the month we prepared for a beamline reconfiguration of the National Ignition Facility (NIF) baseline centered lens, because Beamlet had been originally laid out for a wedged lens which diverted the beam by 2.2°. This required us to offset and repoint the beam in a 4-mirror "mirror tower," which carried the risk of beam rotation and depolarization. Thus the month of November was consumed measuring these beam properties prior to and following the mirror tower installation. In December, we ramped up the 1ω fluence on the mirrors to near their planned operating point, performed an additional week of pinhole closure tests, and assembled, installed and aligned the NIF prototype integrated optics module (IOM) and final optics cell (FOC). The operational and experimental highlights are as follows:

- The pinhole closure campaign was concluded in October, following tests with conical 100-μrad pinholes, conical 150-μrad pinholes, and the new truncated pyramid (square conical) 100-μrad pinhole. The pulse shape at the transport spatial filter was that calculated for the NIF cavity spatial filter in a nominal NIF red line pulse. It required a 20-ns pulse with a contrast of 90:1 at the MOR. The round 100-μrad pinhole showed initial signs of pinhole closure (contrast ratio increases) above 8 kJ, while the pyramidal pinhole closed hard at 7.0 kJ, and even closed for a 2.2-kJ "foot only" pulse. Fortunately these conical pinholes have virtually no backscatter. The conical 150-μrad pinhole remained open with no signs of closure to 12.9 kJ.
- One week was dedicated to measuring the depolarization of Beamlet at the focal plane prior to mirror tower installation. An extensive setup was assembled at the focal plane, and we measured the continuous wave (CW), rod-shot, and system-shot depolarization. We measured 0.18% CW, and only slightly greater for rod and system shots. Following mirror tower installation, the depolarization loss went up to 1%, which is

insignificant for Beamlet. In any case, we attributed the increased loss to alignment issues in the cavity and not the mirrors alone.

- Beamlet was reconfigured for the centered 3ω lens tests in the month of November. All previous 3ω experiments into the focal plane diagnostics (FPD) vessel used the old NIF baseline, the wedged lens, which required the FPD canted by 2.176° counterclockwise from the 1ω output beamline. Rather than move the FPD, which would have been expensive and time consuming, we shifted the 1ω beam using the Beamlet mirror tower. This required an 18.5-cm beam offset to the south, and involved mixed "s" and "p" reflections
- The last of the thin (35-mm) lenses (L2) and one of the tilted 41-mm-thick lenses (L4) were replaced with 46-mm-thick normal-incidence fused-silica lenses. This was in preparation for the high fluences planned with the centered final focus lens tests commencing in January. Slight damage was found on the vacuum surface of L4, leading to the discovery of FOC back-reflection damage within the transport spatial filter, which has since been corrected.
- We executed 10 shots for the mirror testing, ramping up the fluence on the mirror tower transport mirrors to 8 J/cm^2 in a 3-ns pulse. The ultimate goal to be achieved on a later shot series is 12 J/cm^2. We are testing mirrors with 45°, "s" polarization from four different vendors.
- Problems associated with FOC assembly caused us to insert a pinhole closure series in the third week of December. The goal for this short series was to confirm the Optical Science Laser (OSL) result that Ta leaf pinholes close slower than an equivalent configuration of stainless steel pinholes. This experiment had to be performed on Beamlet because of the higher axial intensity at focus compared to OSL. As expected, the ±100-μrad Ta pinholes closed about half as fast as the stainless steel.
- FOC assembly problems were resolved by the end of the third week in December, and we were able to successfully assemble the cell. Several procedures were revised to accomplish this goal, including the main FOC assembly procedure. The cell and IOM were installed with initial alignment during the week before Christmas, and high-fluence 3ω experiments are planned for January. The rest of December was spent on focal-plane-diagnostics alignment and on activation of the Schlieren On-Line Imaging of Damage (SOLID) system, which uses dark field imaging of damage sites. It is our primary damage detection system for the final optics damage tests.

National Ignition Facility

Overall progress on the NIF Project remains satisfactory for the first quarter of FY98. Despite some delays resulting from unanticipated site conditions, the discovery of mammoth bones, and the rains in November, the overall Conventional Facilities construction schedule slippage was minimized through the use of overtime work. Work-around plans are now being developed to determine what future work to accelerate over the duration of the construction, through the use of accelerated performance contracts and change orders, to recover the original schedule. In Special Equipment, the Title II reviews are proceeding on schedule, and in Optics, the progress on facilitization contracts and development activities remains satisfactory.

There were no Level 0, 1, 2, 3 milestones due during the first quarter. There were 12 Department of Energy/Oakland Office (DOE/OAK) Performance Measurement Milestones due, and all but one (Conventional Facilities, Complete Target Bay Foundation Walls & Pilasters) were completed. One milestone in the Optics area—awarding the polarizer substrate contract—was completed four months ahead of schedule.

Key Assurance activities during the first quarter to support litigation activities and the recovery of mammoth bones included: providing support to the DOE for the settlement of 60(b) (Agreement to prepare a Programmatic Environmental Impact Study supplement analyses and to conduct specific evaluations and surveillance of potential buried hazardous materials), initiating the NIF Construction Safety Program, interfacing with institutional surveillance for buried hazardous/toxic and/or radioactive materials, initiating the *Final Safety Analysis Report*, conducting assurance audits, interfacing with the Safety Management Evaluation team on construction safety, and supporting environmental permits. All activities are on schedule.

Site and Conventional Facilities

The Title II design effort on the NIF Conventional Facilities continued to wind down during the first quarter, with all Construction Subcontract Packages (CSPs) at either Title II 100% design complete or already Bid and Awarded. CSP-9 (Laser Building Buildout and Central Plant) was awarded in December to Hensel–Phelps of San Jose, California, for $65.5 million. CSP-6 and CSP-10 (Target Building Shell and Target Building Finish) will be bid as one contract CSP-6/10 (Target Area Building) in February 1998. Parsons Title II engineering design effort will also be complete in February 1998.

Construction of the retaining wall footing at the west end of the Laser Bay was adversely impacted by unanticipated site conditions, design delays in final configuration of the Environmental Protection System,

Walsh Pacific performance problems, and periods of heavy rain during November (see Figure 1). The Target Building portion of the retaining wall footing was remediated and concrete placed in December. Sverdrup (Construction Manager contractor) initially projected a slippage of 10 to 12 weeks in the Conventional Facilities construction schedule, if no activities were accelerated. The current assessment of Project status is that there will be no change to the fourth quarter 01 Level 2 milestone for the end of conventional construction, nor to the fourth quarter 03 Project completion date. However, it is anticipated that there could be a 3 to 6 week impact to the fourth quarter 01 Level 4 milestone for the start-up of the first bundle. There may also be a 6 to 8 week impact to other internal milestones for construction. These impacts are currently being assessed by the construction team and the integrated project scheduling group. Sverdrup is developing a recovery schedule that will require accelerated performance in contracts now being issued and will require change orders to contracts already issued.

Significant work was performed on site to recover and seal rain damaged subgrades, to protect the site by diversion and storage of water during high rainfalls, and to provide all-weather construction access to the jobsite. This site work was performed based upon recommendations from Earth Tech, specialists in wet weather construction from the Seattle area. Sverdrup directed the site remediation activities, and Teichert, a construction subcontractor, performed the work.

Bids were received for CSP-9 (Laser Building Buildout and Central Plant), and the contract was issued to Hensel–Phelps. Competitive bids were received from three bidders with an approximately 2% difference in bids between the two lowest bidders.

Mammoth Bones. Mammoth bones were discovered in the NIF excavation (Switchyard 1 near the Target Area). The bones were recovered by a multidisciplinary team under the direction of a paleontologist who was recommended by the University of California Museum of Paleontology. A permit for the dig was issued by the Department of the Interior, and in accordance with the National Environmental Policy Act, a Supplemental Analysis was issued by the DOE. The bones were preserved in place, encased in fiberglass reinforced plaster, and carefully removed to safe and secure storage at the LLNL site. The work was accomplished in a manner that minimized delays to construction.

FIGURE 1. Target Bay footing construction. (40-60-1297-2604pb01)

Special Equipment

This quarter the Special Equipment FY98 planning was completed, and the Integrated Project Schedule (IPS) has been updated to include the detail Title II plans. Title II guidance for design deliverables has been issued, and Title II design reviews continue to be held on schedule. Procurement reviews were also held. The reliability, availability, and maintainability (RAM) group is helping to produce prototype test plans and procedures.

Laser Systems. During the first quarter there was substantial progress in design and prototyping efforts in Laser Systems. A key accomplishment was resolving the lack of margin in the gain of the amplifier in the baseline design. This was noted at the Title I review and at the NIF Council review in August 1997. An Engineering Change Request (ECR) to allow 23% explosion fraction operation of the NIF amplifier, resulting in provision for increased capacitance in the pulsed power system, was submitted and approved by the NIF Level 4 Change Control Board (CCB) and by the Level 3 Baseline Change Control Board. This change provides for the addition of capacitors at a later date to provide additional gain in the main amplifier if needed. The change provides important contingency in the event of degradation or failure to meet requirements of the amplifier, flashlamps, pulsed power system, and/or main cavity optics.

Optical Pulse Generation. The 17-GHz phase modulator system required for smoothing by spectral dispersion was assembled and tested this quarter. The primary issues are operation of the modulator system and the appearance of amplitude modulation on the laser pulse due to FM to AM conversion of the modulation frequency. The significant modulation observed when the modulation frequency is applied to the fiber-optic system is substantially reduced when the modulation is applied directly to the preamplifier. In addition, assembly of the low-power side of the PAM prototype is under way, and the PAM optical support structure is in procurement with delivery expected in February.

Amplifier. Several meetings were held this quarter to freeze key elements of the amplifier design that must

be detailed in the next six months. The major action items generated at the Title I Review and the NIF Council Amplifier Status Review have been resolved and documented. Gain and wavefront measurements on AMPLAB during the last quarter have so far validated the Amplifier design. An ECR was drafted and submitted to reflect a proposal to adopt slab sizes negotiated with the French Atomic Energy Commission (CEA). This will assure that the laser glass vendors will produce interchangeable slabs for both projects (NIF and Ligne d'Integration Laser [LIL], France's 8-beam prototype of their Laser Megajoule). Subscale tests validated the proposed blast shield seal design, and a decision was made to incorporate removable blast shields in the NIF amplifiers. A full-scale prototype design has been completed and parts ordered for testing on AMPLAB. Preferred blast shield glass and coating methods were chosen based on analysis and tests during the past quarter. The 40-flashlamp lifetime test fixture has been activated and successfully fired under manual control with a full complement of 40 flashlamps.

Pockels Cell. Assembly of the 4×1 operational prototype plasma electrode Pockels cell (PEPC) was completed during the past quarter, and testing of the device has begun. Two apertures (one-half of the device) have demonstrated switching performance that exceeds the NIF specification. Components for the 4×1 PEPC mechanical prototype have arrived, and assembly is in progress. Mounting, vibration, and other mechanical tests will be performed using this prototype over the next several months. A successful Mid-Title II (65%) design review was held for the PEPC in December. No significant issues were identified.

Power Conditioning: The NIF prototype module was assembled and activated during the past quarter at Sandia National Laboratories, Albuquerque. The module was operated at up to 15 kV for 10s of shots. A prototype embedded controller was installed and tested successfully during operation of the prototype. A request for quotations was issued for procurement of the capacitors for the first article module since these are long-lead components. Bids were received and will be evaluated for an award in January 1998. Test runs were completed on several switches, including two tests of the ST-300 and testing of the Russian reverse-switched-dynistor. In addition, arc-drop measurements were made on the ST-300 switch operating at full current. In response to the approval of ECR 189, preliminary planning and scheduling were done to estimate the ECR's impact on the Title II design process. Tests are now under way on NIF capacitors from four vendors with promising results on each to date.

Beam Transport System. After an intensive campaign to resolve all interface control documents and Mid-Title II action items for the Beam Transport System, over 500 prerelease drawings for the Title II Final Design Reviews (Part 1) were completed in December. These drawings will undergo final checking and approval in the next quarter. Final Design reviews were held for three major subsystems that are on or near the critical path for laser installation, the Laser Bay structures, spatial filter vacuum vessels, and the Switchyard 2 structure. Construction Management began a significant ramp-up in activity, initiating a series of construction planning sessions that will ultimately produce a more detailed Integrated Project Schedule (IPS). A full-time construction planner was hired, and a preliminary laser installation strategy was established and reviewed. Design and environmental assessments of Special Equipment laydown areas were initiated, and construction is set to be awarded in January.

Integrated Computer Control System (ICCS). All Mid-Title II (65%) Reviews for WBS 1.5 are now completed. The Mid-Title II Review for Integrated Safety Systems, which includes the Personnel Access Control System and t-1 Abort System, Communications System, and Facility Environmental Monitor were completed in a joint session; no major issues were raised by reviewers. The Mid-Title II Review for Super-visory Software Applications was also completed with no major issues raised. The Mid-Title II Review for Integrated Timing System was held; reviewer comments are pending. The testbed front-end processors, prototype console, network switches, and Software Engineering Computer System were moved into the new ICCS Testbed Facility in B481/R1206. Network modeling tools were evaluated for use in simulating the ICCS computer network of approximately 800 processors. The MIL3 Opnet Modeler tool was selected because of its flexibility and its adoption for use at other DOE sites. The prototype front-end processor was upgraded from the original Datacube processor to the NIF configuration comprised of a Sun Enterprise 3000 server, which promises to be far more scalable to NIF requirements than the previous implementation.

Optomechanical Systems Management. The Optical Mounts group held the Mid-Title II review in November. Drawing packages for the optical mount prototypes were completed and released for fabrication. Prototype testing activity increased in the Final Optics group, and substantial optical design and analysis work was performed (e.g., ray tracing for optical configuration and ghost analysis). The frequency conversion verification system design was completed (prototype), and all parts are on order, with some parts received. Optical design accomplishments included completion of the target chamber damage inspection system, approval of prototype optics drawings for the preamplifier module (PAM), receipt of final design report for the main laser cavity and spatial filter lens design, release of optics drawings for the output sensor prototype, and release of large-aperture window drawings into configuration management. Detailed

product data structures (i.e., drawing trees or indentured parts lists) were assembled, collated, and updated to a uniform format for all line-replaceable units (LRUs) within Opto-Mechanical Systems.

Optical Design. Detailed lens design for the multipass amplifier for the PAM prototype to be built in FY98 was completed this quarter. Fabrication drawings for the prototype were generated, reviewed, approved, and released. The target chamber damage inspection system optical design was also completed, and a comprehensive design report prepared. Optical element fabrication drawings for the output sensor prototype lenses, beamsplitters, and prisms were completed and released through the NIF Product Data Management System for fabrication. A previously reported problem (second-order ghost reflection focusing very close to the Pockels cell) was resolved by shifting the entire periscope structure 120 mm towards the target. In addition, the second stray light workshop was held in November. An update of issues from workshop #1 were presented, the main laser ghosts (including high-order and pencil beams) were reviewed, and the latest results from the extensive modeling of ghost reflections in the final optics were discussed.

Optical Components. The efforts for optics components and production continued on track in the areas of Mirrors, Small Optics, Processing, and Metrology/QA. Some key developments were the completion of efforts to identify all of the small optics required for the NIF in a single spreadsheet, binned into LRUs and types; the modeling of contamination conditions for sol-gel coatings; the completion of demonstrations to vendors and component engineers of the metrology data management system; and the award of the Phase II contract for the LLNL photometer.

Laser Control. The volume of procurements for prototype hardware was increased during the first quarter to provide more opportunities to validate key NIF designs. A few prototypes have already passed NIF lifetime-equivalent tests;. others have generated data that led to important adjustments in their design or in assembly procedures; and many are now in fabrication. Increasing numbers of detailed drawings were also completed as the mechanical designers gained familiarity with the Pro-E CAD tools in the context of detail production. A Pro-E model of the central part of the Transport Spatial Filter (TSF) and the space below it was nearly completed. This model is a key part of defining interfaces in the area. Mechanical and optical design of the input sensor was a major effort this quarter also. Improved packaging now separates the main beamline components requiring the highest level of cleanliness from other components with relaxed cleanliness specifications, placing them in completely separate modules that can be built, installed, or replaced independently.

Target Experimental Systems. Significant accomplishments in the past quarter were the forming of the first two (of 18) plates for the aluminum vacuum chamber at Euroform in France (see Figure 2) and completion of most of the Special Equipment utility designs in the Target Area Building and support pads. The 110-mm-thick aluminum plates were warm-formed (316°C) on a 12,000-ton press between two dish shaped dies, and a preliminary inspection was made using a template. The plates matched contour within 5 mm and no thinning was evident. Prototype testing activity increased in the Final Optics group principally for the actuation system components, debris shield cassette components, and the integrated optics module. Testing of the prototype rail mechanism for debris shield removal was also completed, showing significant particle contamination from the rubbing of the slide mechanism with itself. Particle counts indicated more than 1600 particles of 5 μm or larger over a 4-in. wafer, which equates to a cleanliness level of 600 per Mil Std 1240. An ECR was approved by the Level 4 CCB to add a second "cassette" in the final optics assembly (FOA), and the team began implementing the change. This second, removable cassette would be the optical mount for the diffractive optics. A major factor in the decision was a significant reduction in out-year operating costs for a highly flexible target physics program. A complete set of ghost analysis runs was completed for the optical elements within the FOA consistent with the configuration as required by ECR 180. Of the three million ghosts analyzed through 4^{th} order, 6000 had fluences at focus of greater than 1 J/cm^2. Of those, only two families were at or near optical elements. These were mitigated by adjusting the element spacing in the final optics system. Metrology measurements were made of the mounted crystals used in the recently completed frequency conversion experiments. The 18-in. phase-measuring interferometer in Building 298, with an improved setup, was able to record high-quality transmitted wavefront data that can be used for modeling degradation of frequency conversion due to Δn (change in index of refraction) effects.

FIGURE 2. Forming of Target Chamber plates at Euroform in France. (05-00-0398-0525pb01)

Operations Special Equipment

During the first quarter, Title II design progressed well. Key activities were the preparations for the Mid-Title II (65%) review of the Optics Assembly Building (OAB) Optical Assembly and Alignment Systems and the Transport and Handling 35% Title II Review. A key milestone was completed by getting the LRU and installation schedule under configuration management, including the addition of refurbishing several LRUs per month. In October NIF Procurement awarded two contracts for the Phase 1 Conceptual Design of the Laser Bay Transport System. By the end of the first quarter, the Phase 1 designs were complete at both contractors (RedZone Robotics, Inc. and Mentor AGVS), and the Conceptual Design documents were received. The assembly of the hardware for the cover removal mechanism for the Bottom Loading (BL) Universal Canister was completed, and "dirty testing" of the cover removal has been initiated. The BL canister nitrogen gas purge testing has also started. Eighty percent of the OAB Special Equipment prototype equipment has been procured, and cleanliness and function testing is beginning.

Start-Up Activities

The updated IPS database was functional on October 31, with over 10,000 activities, and is now being used to status the Project each month. The IPS includes Level 0–4 Project milestones, interfaces, and detailed activities; integrates key technology activities and milestones; and includes FY98 Cost Account Plan schedules. To supplement the IPS, a detailed LRU installation plan (in the form of a chart) has been developed, which describes the number of LRUs of each type to be installed on a monthly basis throughout the Special Equipment installation phase of the Project. Early in the quarter the first bundle working group progressed through an initial discussion and flow diagram of all integrated operational test procedures for first laser bundle start-up. Procedures reviewed during October include the Diagnostic Target Shot procedures, the Precision Diagnostics, the Computer Controls System requirements, Target Area Beam Transport, Final Optics Assembly, beam alignment to Target Chamber Center, and an update on the Main Laser activation steps. Several first quarter Start-Up weekly meetings discussed the coordination with NIF/ICF Program ignition planning efforts. An update on hohlraum energetics experiments and backscatter diagnostics planning was presented, followed by a discussion of start-up test criteria and expected laser performance at completion of a laser bundle start-up.

Optics Technology

Key enabling technology areas are coming to critical demonstration points in the second quarter, and the Optics Technology organization is now shifting its focus from the facilitization contracts, which are proceeding without significant problems, towards those demonstrations and preparation for the pending pilot production effort. Tinsley presented its revised facilitization plan based on a delay until March for the beginning of site preparation due to the current weather. To preserve the pilot production schedule, Tinsley has proposed performing its NIF equipment acceptance testing in its existing facility, and then transferring the equipment to the NIF facility in August 1998. Schott's phase II building is now completely enclosed, which will allow them to complete the construction on schedule without weather delays. Hoya's new facility has the offices, conference room, and elevator completed except for furnishings. The Zygo facility modifications are 94% complete, with most of the work remaining in the shipping receiving area. Assembly of the first relay plane machine was completed; a Zygo review team conducted an acceptance audit; and the machine was found to be acceptable. The contract to retrofit and refurbish the 160" continuous polisher at Eastman Kodak has been awarded, and the work is expected to be complete by May. Tinsley has completed a second high-speed lapping and polishing machine as part of lens development. This machine is the third and final of its type to be built during NIF development at Tinsley and incorporates advancements learned from the design, build, and operation of the previous machines. Many of the long-lead components for the four new 1000-L tanks have arrived at LLNL. One of the four glass vessels is at LLNL, the other three are expected to arrive in late January. All four water bath housings, all support framework/spider systems, and nearly all of the control and diagnostic equipment are on site. LLNL has selected coating vendors for opening negotiations for the coating facilitization contract awards. The first full-sized color separation grating was completed and delivered on schedule to Beamlet in November. The part exceeded specifications with <1% 1ω and 2ω zero order transmission. At 92% transmission in the 3ω zero order, it missed the specification of >95%. No antireflection coating is currently known to be compatible with the NIF 3ω fluence targets of 14 J/cm^2. A plan has been defined to evaluate scandia/silica antireflective coatings from the University of Rochester Laboratory for Laser Energetics and spin-coated sol-gel coatings done at LLNL. Also this quarter, initial inspection of existing 7940/7980 shows <80 μm inclusions have existed in significant quantity in at least some Nova

optics. Evidence was also found that <30 μm inclusions have damage in the hottest spot on Nova (input SF7 lens), but these bulk damage sites did not grow to >35 μm at the 1ω fluence of ~15 J/cm^2.

Upcoming Major Activities

During the second quarter of FY98, Conventional Facilities construction will complete the Target Bay mat foundations and the backfill of the mass excavation around the Target Bay. Work on the Optics Assembly Building will begin, and the "Notice to Proceed" will be given for Construction Subcontract Package 9, Laser Building & Central Plant. Special Equipment will continue with several Mid-Title II (65%) Design Reviews, and Title II (100%) Design Reviews will take place in the area of computer systems. In Optics, the activities for bidding and negotiating the optics facilitization contracts will continue.